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ELECTRICAL PROPERTIES OF INDIAN SOILS AT MEDIUM BROADCAST FREQUENCIES

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ABSTRACT. The electrical conductivity and the effective dielectric constant of soils from different places of India have been determined each for seven different frequencies within the medium broadcast frequency range and also with different moisture contents by the differential transformer method. Samples of soil were produced from Dacca, Calcutta, Lucknow, Delhi, Lahore, Peshawar, Bombay, Calicut (Madras Presidency), and Trichinopoly. The conductivity was observed to increase with both frequency and moisture content. But the rate of increase with moisture was very great while that with frequency was small. The effective dielectric constant was found to decrease with frequency and to increase with moisture contents.

From the observed values of the soil conductivity at 20% moisture the field strength attenuation curves for all the stations (except Delhi) of the All-India Radio have been drawn.

Suitable antenna-heights in relation to wave lengths have also been calculated for all the A.I.R. transmitting stations on the basis of the measured values of the soil conductivity.

INTRODUCTION

Owing to the rapid development of broadcasting service, the determination of the electrical constants of the soil is of considerable practical importance, especially in the case of medium radio frequencies. The methods generally employed for the purpose are:—(1) the field-method and (2) the laboratory method. The latter method found favour with recent workers, since the soil can be studied under various controlled conditions.

Ratcliff and White (1930), made direct measurements of the electrical constants of some specimens of English soil by a laboratory method with medium radio-frequency fields. Previous to this work some measurements of the soil constants were made by Bairsto (1912). Similar investigations on medium frequencies were carried out by Smith-Rose (1933), in an elaborate manner with specimens of Cambridge soil for various values of moisture content and at different frequencies. Soils were also studied at medium frequencies in America by Dellinger (1933) and in Australia by Cheery (1930). In India Sengupta and Khastgir (1936), studied a few specimens of Dacca soil for medium frequencies. Ansari, Toshniwal and Toshniwal (1940), also studied on medium frequencies, the soil of Allahabad for various values of moisture content at three different frequencies. Some direct measurements were also carried out at Benares by Banerjee and Joshi (1937), on medium frequencies. The soil conductivity at medium broadcast frequency was determined by actual field measurements by

Roy (1936), in the case of Calcutta soil and by the Research department of the All-India Radio (Report...1940), in the case of Lahore, Lucknow and Delhi soils.

THE SCOPE OF THE INVESTIGATION

So far there has been no attempt at any systematic study of the electrical properties of soils from different parts of India. The rapid development of broadcasting in India during recent years, therefore, urged us to undertake a study of soil samples from Dacca to Peshawar and from Delhi to Trichinopoly. The samples were accordingly procured* from the places where there are broadcasting centres of the All-India Radio. The soils from the different places, *viz.*, Dacca, Calcutta, Lucknow, Delhi, Lahore, Peshawar, Bombay, Calicut (Madras Presidency) and Trichinopoly, can be taken to represent practically all types of Indian soils. A study of the electrical properties of these soils would, no doubt, be useful in determining service-areas, allocating suitable frequencies to transmitting stations, selecting suitable antenna heights and in various other ways. Measurements were, therefore, made of the effective dielectric constant and electrical conductivity of the different soils for various moisture contents and for various frequencies covering the medium broadcast frequency channels. The well-known differential transformer method was employed for the purpose. Calculations of service-areas and suitable antenna-heights in relation to wave lengths of the waves transmitted are also given.

EXPERIMENTAL DETAILS

To eliminate stray fields, the differential transformer was properly shielded. The oscillator was placed at some distance to avoid its direct effect of any part of the experimental arrangement. The connecting link between the coupling coil and the tuning condenser were also shielded.

The soil-condenser consisted of two rectangular parallel plates, each of area 3.1×4.3 sq. cm. and its capacity was 8 $\mu\mu$f. when empty. The soil condenser plates were mounted on a rectangular framework made of ebonite. When filled up with soil it was bounded on all sides by thick ebonite sheets. The ramming of soil in the condenser was made such as it is generally found in the field.

EXPERIMENTAL RESULTS

The variations of the soil constants with moisture contents for the nine different Indian soils for 1 Mc/s field are illustrated in Figs. 1 and 2. The variations with frequency are illustrated in Figs. 3 and 4 for 15% moisture content.

(a) *Conductivity of the Soil*

For each sample, the electrical conductivity was determined for six frequencies within the range 600 Kc/s to 1500 Kc/s. In each case the value

*The only exception was Madras. The sample of soil profile was from Calicut in the Madras Presidency.

increased with increasing frequencies but the change was very small. On the other hand, the results obtained in the case of moisture variations showed a large increase with increasing moisture content. For smaller percentage

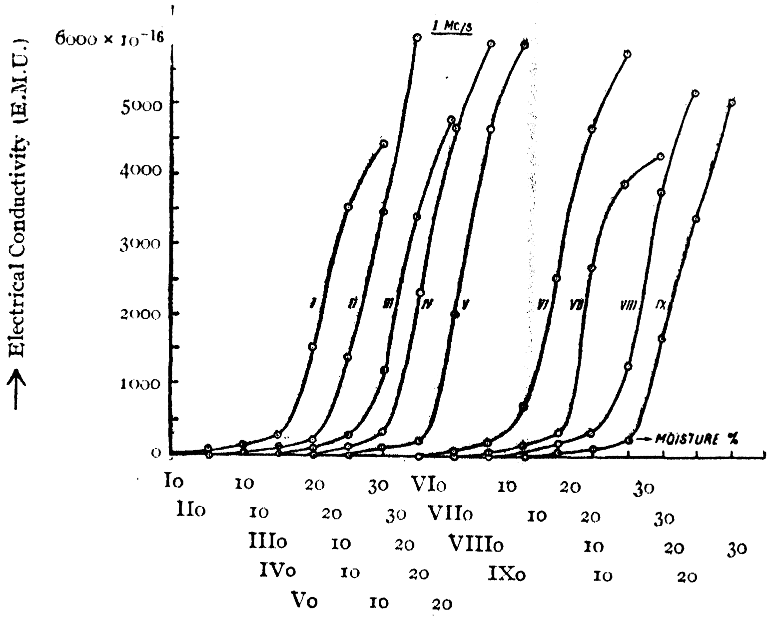

FIG. 1

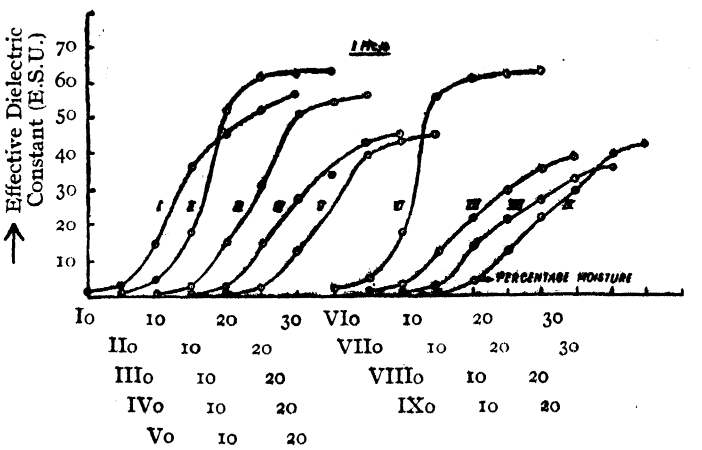

FIG. 2

of moisture, the variations was small while for larger percentages it was rapid. With further increase in the moisture content the results showed a tendency to become practically constant. The average value of σ was found to be about 2×10^{-16} *e.m.u.* when the sample was dry and about $.5 \times 10^{-13}$ *e.m.u.* at 30% moisture. At 20% moisture the average value was about 2×10^{-13} *e.m.u.*

The conductivity values, as obtained by Sengupta and Khastgir with two specimens of Dacca soil, are somewhat lower than the values obtained by us. Ansari, Toshniwal and Toshniwal's values for Allahabad soil and those for Benares soil, as obtained by Joshi, are of the same order as ours.

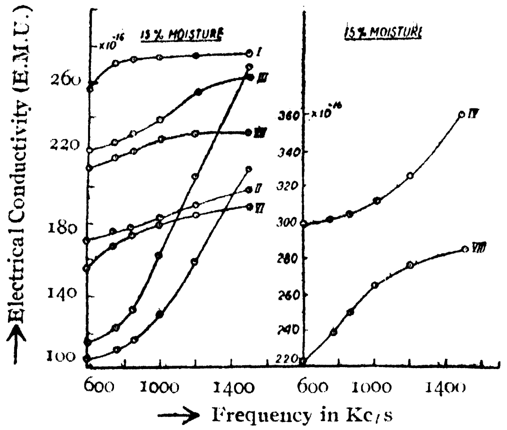

FIG. 3

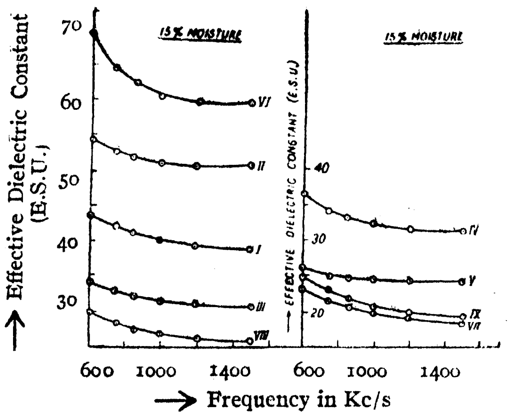

FIG. 4

According to K. Roy, the average value of the conductivity for Calcutta soil as determined by actual fieldstrength measurements, outside the city area could be taken as 2×10^{-13} *e.m.u.* The Research Department of A.I.R. found that for Lahore, Lucknow and Delhi soils, the conductivity values were 1.5×10^{-13} *e.m.u.*, 1.75×19^{-13} *e.m.u.* and $1—1.5 \times 10^{-13}$ *e.m.u.* respectively in the medium frequency range.

The measurements of the soil constants in Europe, America and Australia also give values which are of the same order as the values obtained with the Indian soils.

(*b*) *Effective Dielectric Constant of the Soils*

The rate of rise of the dielectric constant value was found to be very rapid for smaller percentage of moisture content. The rate varied appreciably in the different soils. For Dacca, Calcutta and Lucknow soils, the dielectric constant increased extremely rapidly when the moisture content was varied from 0 to 15%, whereas for the other soils, the rate of variation within that range of moisture content was much smaller. In the comparison of the dielectric constants of the different soils for 15% moisture content, the Dacca, Calcutta and Lucknow soils, therefore, showed comparatively large dielectric constant values at a frequency of 1000 Kc/s.

CALCULATION OF SERVICE AREAS

The fieldstrength attenuation curves for the different A.I.R. stations have been computed from the standard formula, the ground attenuation factor having been calculated from Van der Pol's expression. In the computation of the attenuation curves, the conductivity values of the different soils for 20% moisture content have been taken.

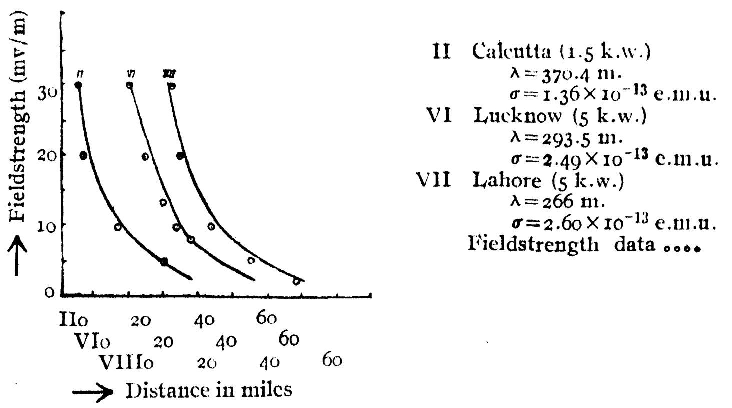

FIG. 5

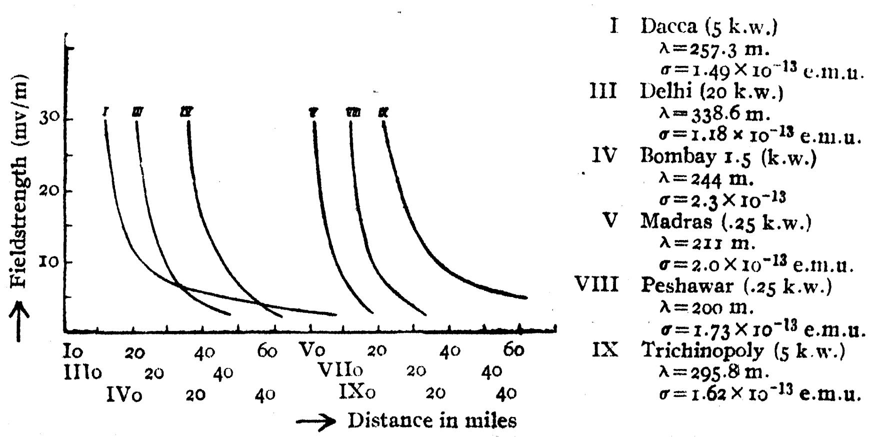

FIG. 6

Figs. 5 and 6 show the computed fieldstrength attenuation curves for all the stations of A I.R.* In the computed curves for Calcutta, Lahore and Lucknow shown in Fig. 5 the fieldstrength values actually obtained by K. Roy and the Research Department of A.I.R. are shown for comparison. The agreement is indeed very good. The fieldstrength values for the Delhi station are not shown in the graph, since the Delhi transmitter does not radiate energy uniformly in all directions.

In a tropical country like India, the atmospheric disturbances are considerable, so that a fieldstrength of 20 mv/m is generally regarded as good for radio reception in all seasons of the year. Following this standard, the service areas for all the A.I.R. medium wave stations as obtained from the computed attenuation curves are shown in Table I.

TABLE I

Service areas for a fieldstrength of 20 mv./m.

Serial number	A.I.R. stations	Power (Kw)	Wavelengths ((metres)	Electrical conductivity of soils for 20% moisture (e.m.u.)	Service areas (miles)	h/λ for fading-free reception.
I	Dacca	5.0	257.1	1.49×10^{-13}	16	.563
II	Calcutta	1.5	370.4	1.36 ,,	9	.581
III	Delhi	20.0	338.6	1.18 ,,	—	.573
IV	Bombay	1.5	244.0	2.3 ,,	8	.573
V	Madras	0.25	211.0	2.0 ,,	4	.559
VI	Lucknow	5.0	293.5	2.49 ,,	16	.584
VII	Lahore	5.0	276.0	2.63 ,,	16	.584
VIII	Peshawar	0.25	200.0	1.73 ,,	4	.610
IX	Trichinopoly	5.0	295.8	1.62 ,,	17	.600

DETERMINATION OF SUITABLE ANTENNA-HEIGHTS

It has been shown by Ballantine (1943), that by a suitable choice of antenna-height the strength of the sky wave can be greatly reduced. This will obviously diminish fading. At great distances fading is a great disturbing factor in radio reception. So it was thought desirable to find out suitable antenna-heights in relation to the frequencies used by the broadcasting stations of All-India Radio.

A set of h/λ curves (not shown in the table) for medium broadcast frequencies corresponding to the conductivity values of the different soils were computed after the manner of Ballantine and the antenna-heights for the desired frequen-

*The attenuation curve for the Madras station was computed by supposing the electrical conductivity of the Madras soil essentially the same as that of Calicut (Madras Presidency). The soil conductivity of Calicut was taken.

cies, were determined from these curves. The results are shown in the last column of Table I.

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